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Incorporation of Direct and Indirect Climate Change Effects Into a Probabilistic Pesticides Risk Assessment: A Northern European Case Study

Highlights

- Novel probabilistic approach to assess the environmental risk of pesticides under future scenarios
- Bayesian Network integrating different types of information and quantifies uncertainty under various scenarios and for all components of the model
- Exposure prediction model settings can incorporate:
  - different crop and soil types,
  - various other pesticides,
  - more application scenarios, and
  - a selection of climate models.

Background

- In Norway, climate change (CC) is expected to result in an increase in temperature and precipitation.
- Expected CC effects can cause an increase in occurrence of fungal, plant disease, and insect pests.
- Adaptation to CC may lead to changes in agricultural practices (Hanssen-Bauer et al., 2015).
- Typical risk assessment lacks consideration of variability and uncertainty to hazardous pesticides and other factors influencing the exposure to or effects of them (Belanger & Carr, 2020).

Our main study goals were:

- To develop a probabilistic model - Bayesian network (BN) - that characterize environmental risk of pesticides under future CC scenarios,
- To include direct and indirect effects of CC scenarios (such as meteorological conditions and pesticide application),
- To quantify uncertainty and incorporate it in the probabilistic risk characterization.

Approach

The exposure concentration was predicted with the World Integrated System for Pesticide Exposure (WISPE) platform (Bolli et al., 2013):

- It can be run with several realistic crop, climate, pesticide application and soil scenarios (e.g. predicted meteorological data for 2000-2100 - A1B emission scenario), and for a representative field side).
- Three application scenarios are used: baseline (current practice), baseline-50% (Green deal), and baseline+50% (Worst-case practice).
- The platform was run for five pesticides: MCPA, fluroxypyr-meptyl and clopyralid (herbicides), trifloxystrobin and prothioconazole (fungicides).

BNs can act as a meta-model that integrates different types of information, from e.g. climate projections, pesticide exposure models (e.g. process-based exposure model) and toxicity testing (Mentzel et al., 2021).

The proposed BN model consists of four modules (Fig. 1):

1. Scenario module: contains a scenario node that is defined by climate and application.
2. Exposure module: the scenarios determine the instantaneous concentration and its probability distribution (Fig. 2).
3. Effect module: its effect distribution is based on either no effect concentration (NOEC) or half maximal effective concentration (EC50) distribution – log-normal distribution, similar to a species sensitivity distribution but not used to derive a predicted no effect concentration.
4. Risk characterization module: composed of exposure: effect ratio node that together with an appropriate precautionary factor predicts the probabilities of the risk quotient (RQ) intervals. Typically, risk is assumed if RQ > 1 (Mentzel et al., 2021).

Figure 1 Example of the BN parameterized for fluroxypyr-meptyl, with a baseline+50% application, global climate model C1, time period of 2035-2056, for a time since application of 1 day and a EC50 based effect distribution.

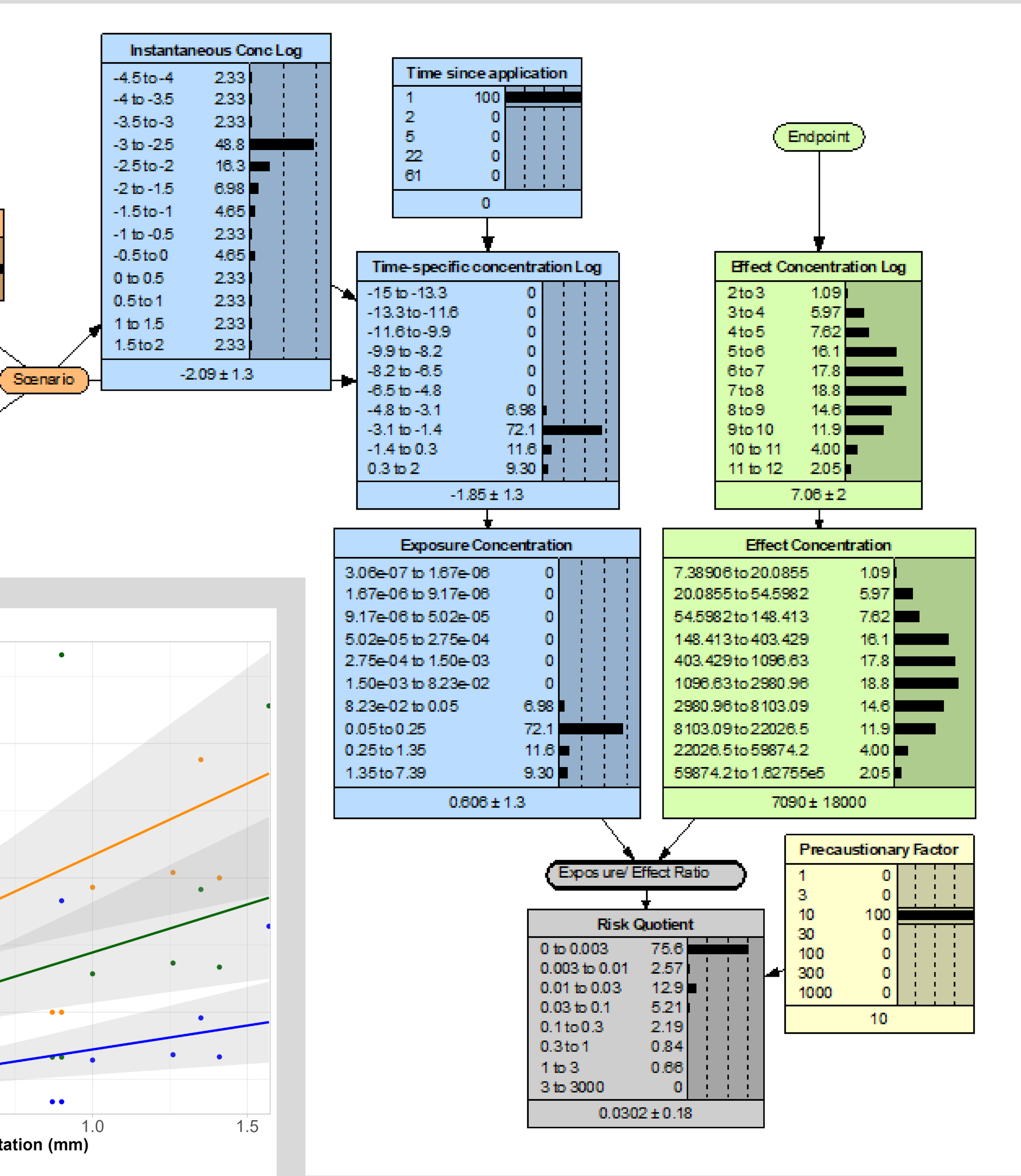
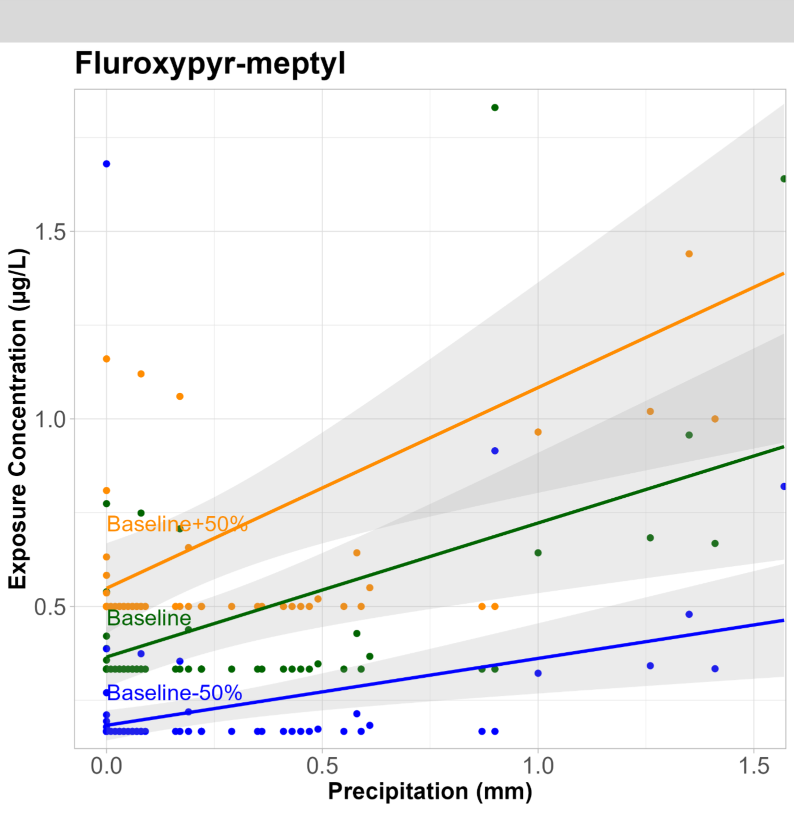


Figure 2 Example of the effect of precipitation on the pesticide exposure concentration under the three application scenarios according to the WISPE platform outputs.



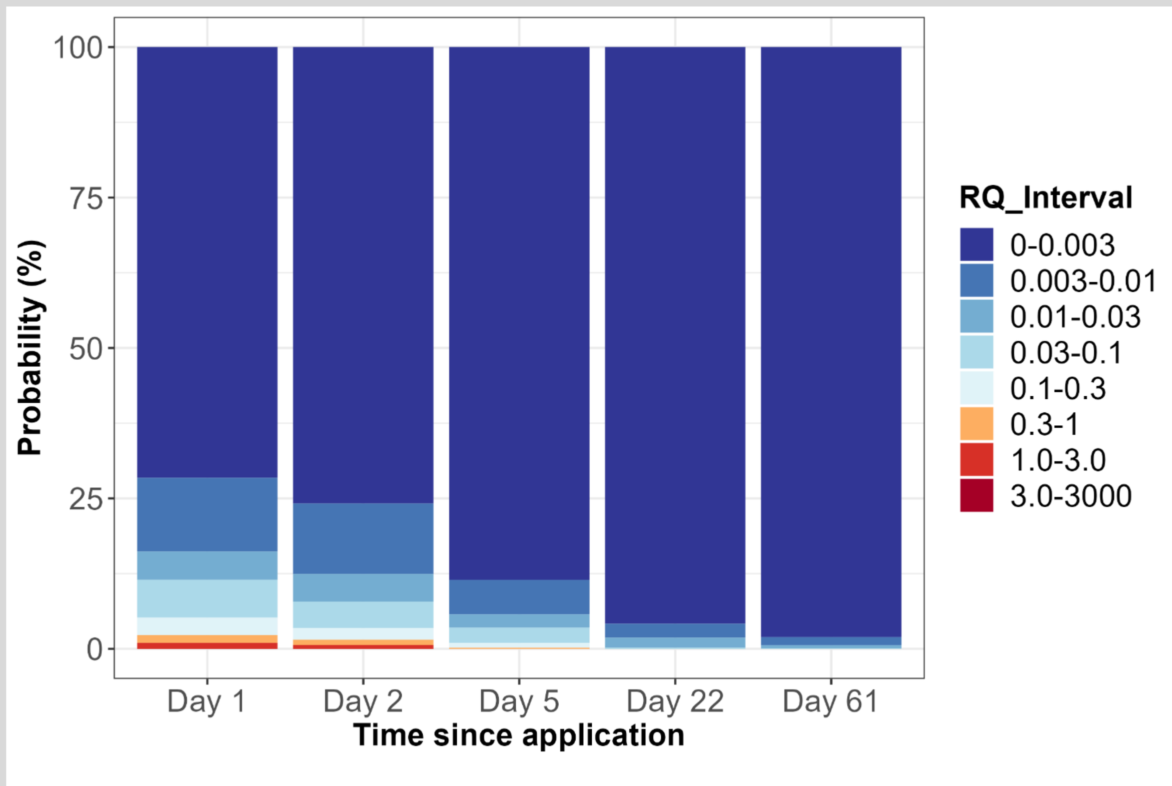


Figure 3 Example of fluroxypyr-meptyl risk quotient distribution over time for 1, 2, 5, 22, and 61 days after application, for the baseline application, climate model C1 and the time interval of 2070-2100 with a NOEC based effect distribution.

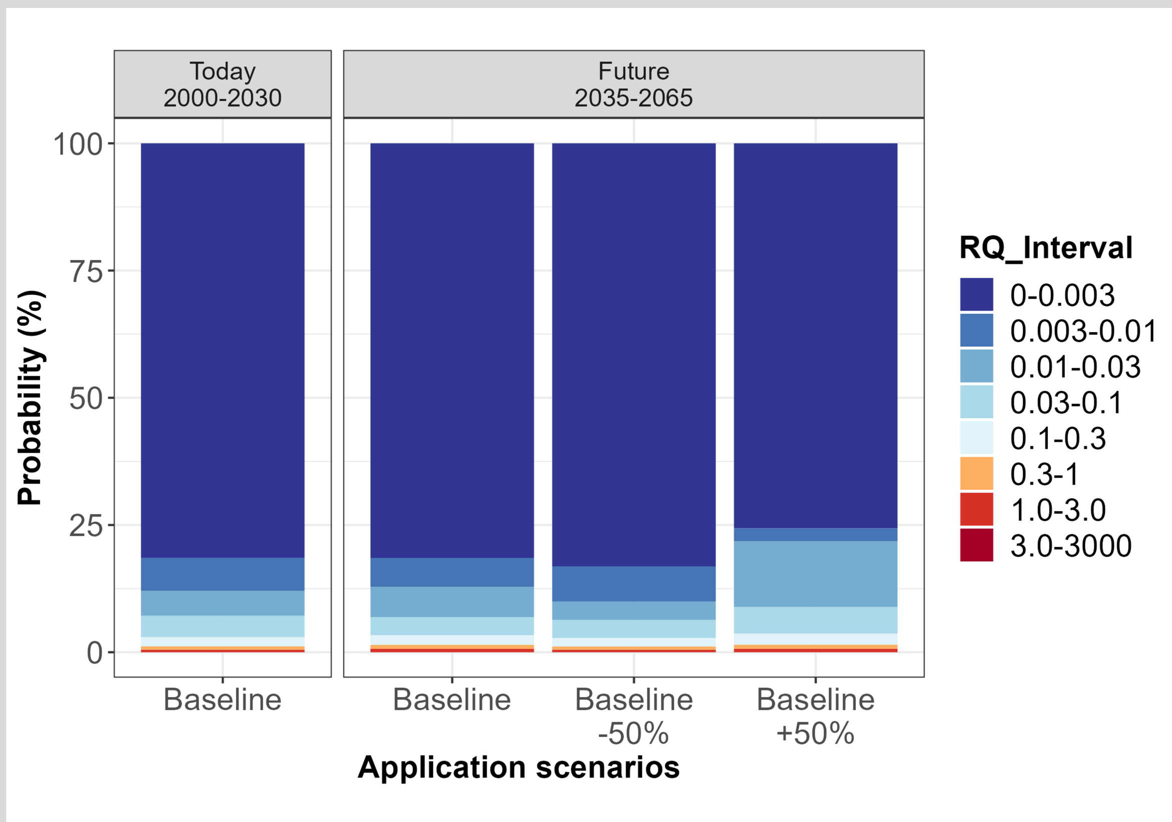


Figure 4 Example risk quotient distribution for fluroxypyr-meptyl derived with current and future application scenarios, for one day since application, with a EC50 based effect distribution.

Results

Two examples are displayed for the risk quotient node output of the developed BN.

RQ distribution over time (see Fig.3):

- RQ is most likely in lower intervals.
- At Day 1, the highest probability is predicted for the RQ to be above 1.
- Already at Day 5, the RQ is below 1 with a likelihood of a 100%.

RQ distribution for expected scenarios (see Fig. 4):

- For current application practice with current climate, the RQ is predicted to be below 1 at 99%.
- In future:
  - RQ distribution with the same application scenario stays the same,
  - There is a slight shift towards lower RQ intervals for the baseline-50% scenario, and
  - The probability for the RQ to be above 1 is highest with the baseline+50% application scenario.

Future perspectives

- Probabilistic risk assessment approaches need to account for variability and uncertainty in CC.
- Updated RCP emission scenarios and bias corrected climate projections are needed for more realistic predictions.
- BNs are a promising method for predicting risk of complex environmental conditions and accounting for uncertainty in prediction

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